PRESTO! "GROWING" PARTS FROM LIQUID PLASTIC

A new process called stereolithography uses a computer-guided laser to "grow" 3-D prototype parts from photosensitive liquid plastic. Quicker and cheaper than traditional model-making methods, it's helping manufacturers hurry new products to market.

By STUART F. BROWN

A purplish pinpoint of laser light dances back and forth across the surface of a pool of murky liquid polymer, slowly tracing a cross section of an object: a plastic connector used in a medical device.

Soon the partially formed tubing connector for an intravenous feeding apparatus descends a few thousandths of an inch in the pool and the laser resumes its flickering course, outlining the part once again. Each time the laser makes a pass, its ultraviolet light hardens another thin layer of the photosensitive plastic, literally "growing" a solid plastic part from the bottom up. The result is a finished model of the connector, ready for testing by product engineers.

There's an almost magical quality to stereolithography, a process that can coalesce liquid polymers into dazzlingly complex solid structures in a matter of hours. Product designers in companies making equipment ranging from jet engines to computers are using the model-making method to explore new part designs quickly.

The technique is helping them to overcome a traditional bottleneck in product development: the large amount of effort and expense required to produce prototypes of new designs. And as global markets for all sorts of products become increasingly competitive, it's vital for companies to be able to revamp and fine tune their wares rapidly to keep up with their rivals.

Looking a little further ahead, it's likely that surgeons will fabricate models of human bones or prosthetic implants using the process, while auto designers may use it to create new car-body shapes.

"Stereolithography saves us a lot of time and money," says Mike McEvoy, director of computer-aided design at Baxter Healthcare Corp. in Round Lake, Ill., as he hovers proudly around his machine. "We make 110,000 different medical-supply products, and we design hundreds of new plastic parts each year. This process has shortened the time it takes us to optimize a new design from six months to a couple of weeks."

Apple Computer in Cupertino, Calif., uses the process to make models of the plastic housings for its computer equipment. "It gives us almost instant prototypes. We can design our parts on three-dimensional CAD [computer-aided design] terminals and then go right to a stereolithography model without ever making drawings," says Rodney Archer, manager of mechanical design technology.

Refining designs

All over the industrialized world, product designers sit at CAD terminals creating three-dimensional descriptions of parts and assemblies on multicolored computer displays. These powerful computer systems have drastically cut the amount of time it takes to "draft" the dimensions of a new part.

Once a part has been designed on a CAD system, the next step is to make a prototype, or model, that the designer can hold in his hand to see how it looks, feels, and fits with its mating components, as well as how it functions. Companies that manufacture complex products such as motor vehicles, aircraft, or electronic equipment make countless prototype parts each year. It's a process that requires skilled technicians and a lot of time and money.

Frequently, after studying the prototype he ordered, a designer will realize that a major change is required. Then the expensive prototype tooling gets sent to the scrap heap, a costly routine that may be repeated again and again before the new design is refined to the point where it is ready to go into production.

The stereolithography process is the invention of Charles W. Hull, a California-based engineer with a background in designing scientific research equipment. "Having spent plenty of time waiting around for prototype parts I needed, I was aware of how much time it takes to develop new products," he explains. "In 1980 I was working with photopolymers that harden in ultraviolet light. I started thinking that there must be some way of using them to make three-dimensional models or prototypes of things quickly."

At first Hull hoped to use holograms to form a part in one shot, but he found that there wasn't any practical way to convert the CAD description of a part into information that could be used to make the entire item. "I realized it made sense to break the object up into cross sections, or layers, and build it from the bottom up," he explains. "Working out the mechanics of aiming the laser beam wasn't really too difficult. The hard part was writing the software that 'slices' the electronic model in the CAD data base so it can be used one layer at a time."

The software takes the CAD-generated description of a part's surface and divides it into triangular patches small enough to give the desired degree of surface finish. The program then passes knifelike horizontal planes

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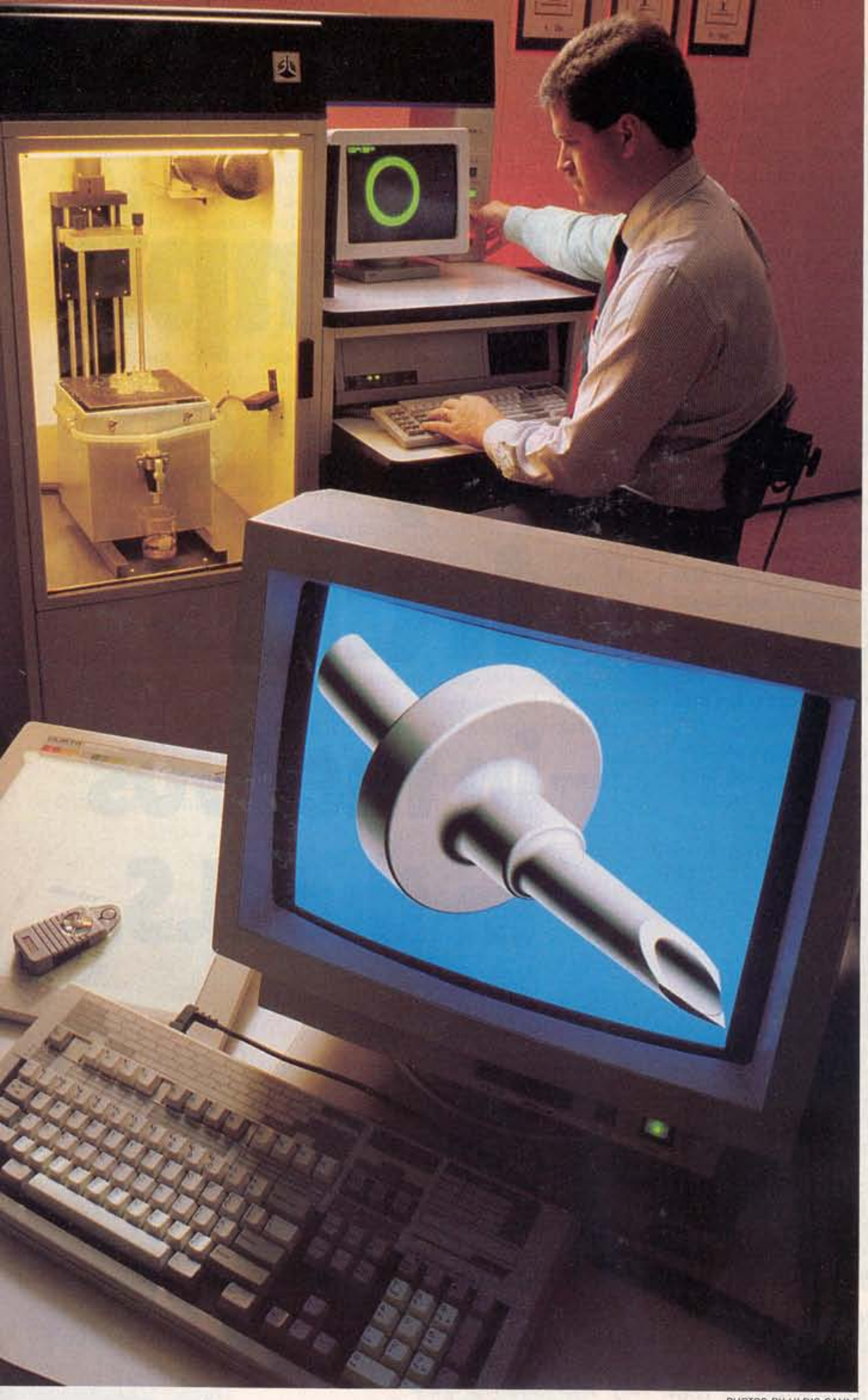
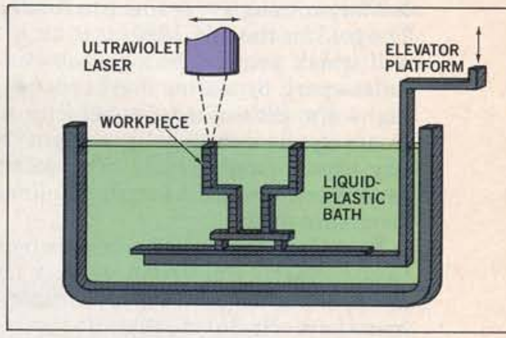




The screen (left) on the three-dimensional CAD terminal in the foreground shows a design for a plastic connector used in intravenous-feeding equipment. Visible on the stereolithography system's greenish computer screen is the "slice" of the part the machine is actually producing. Removed from the plastic bath (top), a quintet of identical connectors are supported by thin plastic webbing that will be cut away when the process is completed. 3D Systems' StereoLithography Apparatus (drawing above) consists of an ultraviolet laser that can be aimed left-right or fore-and-aft under computer control. The workpiece rests on an elevator platform that can be raised or lowered. A pinpoint laser beam travels across the surface of the photosensitive liquid plastic bath, hardening the liquid where it strikes. Once this layer of the part is completed, the elevator descends, and the next layer is formed.

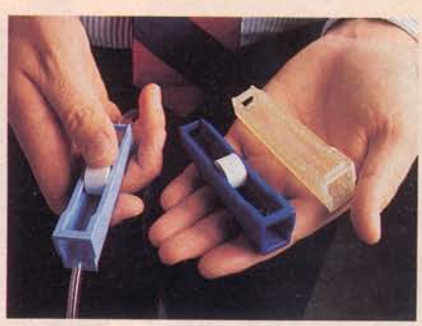
PHOTOS BY ULDIS SAULE

BUT WILL THE NURSES LIKE IT?

"The clear part in my hand [right] is a stereolithography model of a roller clamp used in blood-transfusion equipment," says Thomas J. Mueller, manager of computer-aided engineering development at Baxter Healthcare Corp. "The dark blue part is the same thing painted to look like a production part.

"We wanted to introduce this new clamp, but we weren't sure whether nurses would like the feel of it—after all, they're the ones who have to work with the equipment. Traditionally we would have made a prototype mold to produce a trial part at a cost of about $20,000. It would take six to eight weeks to get the mold, and we might well have to start over after we saw the first part and realized the mold needed to be changed.

"We had the prototype clamps completed on the 3-D machine and painted two days after they were designed. Then we let our marketing department take them to a hospital and have nurses evaluate them to see if they felt OK. It turned out that they liked the clamps, so we invested in the production tooling to start making them. The light blue clamp is the one that we sell."—*S. F. B.*



"Growing" parts

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through the CAD model, slicing it into thin layers: Think of it as the mathematic equivalent of a hard-boiled-egg slicer. The slices are then used one by one to generate the laser-aiming commands that photochemically "grow" the prototype one layer at a time.

The second-generation stereolithography machine now being produced by Hull's firm, 3D Systems, in Valencia, Calif., can make parts measuring up to 10 inches in each dimension. Models of larger parts can be fabricated by dividing them into sections.

3D Systems is currently working on developing equipment to make models of much larger parts. "We think that you can ultimately make car bodies," Hull says. If this proves true, the auto industry, which invests a tremendous amount of time and money in developing new body designs, is bound to take an interest in the process.

Another enticing future application of stereolithography is making models of injured bones or other features located inside the bodies of patients by using CAT-scan data to drive the 3-D machine. A skull from a patient who suffered a head injury has already been modeled in this fashion. Such a model could let a surgeon preview what he will encounter during an operation.

3D Systems isn't the only company using the technique of slicing a CAD model to build prototypes a layer at a time. Hydronetics, Inc., in Chicago has come up with two variations on the theme. One method called laminated object manufacturing uses stacks of thin plastic or copper-coated steel sheets. A computer-driven laser cuts the appropriate outline for each layer, while its heat fuses the sheets together to form a solid part.

Hydronetics' second technique uses laser heat to solidify powdered plastic. After each layer has been formed, a dispensing system spreads another layer of powder, and the laser goes to work. Nova Automation Corp. in Austin, Texas, has developed a similar process, which it calls selective laser sintering. These three systems have not yet reached the market.

Two options: quicker or better

"There are two ways you can use a technology like stereolithography," Apple Computer's Archer reflects. "You can speed up your design process by getting the prototypes made faster. Or you can investigate more variations on your design, and finish at the same time with a design that's better because you looked at more options. I prefer the latter course. I think the result will be that our customers get more-functional, better-quality products from us." PS